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BLOCK PARTS FOR GLASS-MAKING FURNACES

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Borovichi Refractory Plant JSC has performed a complex of works on manufacturing fireclay block parts for the lower structure of glass-making furnaces. The characteristics of the technology for producing the parts and the process line as well as upgrading technological equipment and guaranteeing product quality are examined. The physical and chemical properties of ShSU-33 and MLS-62 parts and the advantages of such parts over similar products from other manufacturers are presented.

Block parts are ordinarily used in the masonry at the bottom of the melting tank of glass-making furnaces [1]. Before cast baddeleito-corundum parts came into use, because of their large size and the small number of seams large aluminosilicate parts provided the required furnace-tank life; now they also impart stability to the bottom structure of the furnace and reliable thermal insulation there.

Work on replacing fired fireclay parts with concrete parts is now being performed [2]. It should be noted that unfired low-cement concrete parts must be put into the operating temperature regime correctly because when heated they undergo a continuous series of chemical and phase transformations: dehydration of the cement, a reaction forming calcium hexa-aluminate in the matrix, and interaction of the calcium hexa-aluminate with the aluminosilicate component of the matrix with formation of mullite and a glass phase [3]. In the course of these transformations, stresses accumulate in the parts as a result of volume changes during phase transitions, and these stresses can weaken the parts and even cause them to fail in the masonry. In fired fireclay parts, the formation of the phase composition is completed during firing at the manufacturing plant and remains unchanged during heating and operation of the furnace over the entire run.

All concrete parts (fired and unfired) contain refractory cement — calcium aluminates, chemically less resistant to silicate glass, especially at high temperatures, which can result in chemical corrosion and service life reduction.

In 2005, because Podol'skogneupor JSC ceased the production of fireclay block parts, the production of these parts was organized at Borovichi Refractory Plant JSC so as not to lose in Russia the production of the refractory products required by glass enterprises.

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The K-5000 hydraulic press (Fig. 1) and the SM-1500 continuous intense-action mixer manufactured by Tyazhstankogidropress JSC (Novosibirsk) formed the basis for the mixing-forming line. The powerful 5000 ton K-5000 hydraulic press (Germany) is a unique machine, which makes it possible to provide the force required for semi-dry pressing of large parts. Stromizmeritel' JSC (Nizhny Novgorod) manufactures and delivers mass proportioning equipment for the mixer; this equipment is well-known and needs no further consideration. In addition, a sieve was installed in front of the bucket to prevent size-separation of the mass when the bucket is loaded. Two magnetic iron separators were installed in the mass feed line from the mixer into the process bucket to decrease the likelihood of spalling.

Fig. 1. K-5000 press.

Fig. 2. Cutting of parts on a cutting-stone machine tool.

The process line also contained a drying enclosure for preliminary drying of parts and a drying chamber. An operating tunnel furnace from the steel pouring section is used to fire the parts. When necessary, the fired parts can be ground in a special machine ("Wassmer," German) for grinding large parts. This machine is equipped with two parallel laser rules for precise setting of the grinding edges. The parts are milled with a cutting-stone machine tool (Fig. 2).

The need for upgrading and automating the equipment became clear during assembly and operation of the process equipment.

Specialists from the Borovichi Works automated the mixing-proportioning line using modern microprocessor technology. Information on the composition of the batch, amount of liquid binder, and duration of each stage of compact preparation is fed not only into the computer of the section engineer but also to control stations (central plant laboratory, technical division).

The upgrading of the K-5000 press merits special attention. The press was completely disassembled for shipment from Podol'sk to Borovichi. When the press was assembled and set up, new columns and guides were installed and essentially all components of the hydraulic system were replaced. Specialists from VNIIMETMASh JSC and the Tyazhpressmash Works in Ryazan' performed the leveling of the press frame and set the vertical alignment of the columns followed by thermal tightening of the nuts, which ensured that the press remains rigid and the pressing crosspieces and the filling carriage of the press move smoothly.

When the mix was loaded for pressing the parts, because of the large height differential between the loading hopper of the press and the die pocket, size-separation occurred in the mix; this was observed visually as horizontal bands with different grain-size on the lateral boundaries. As result of size-separation, the filling box and especially its front part were not completely filled, which resulted in nonuniform pressing of the green compacts and high (up to 85%) rejection rates due to cracks even when the mix in the die cavity was manually smoothed.

Specialists from the central laboratory of automation and mechanization at Borovichi Refractory Plant JSC completely re-examined the construction of the apparatus [4] used to pour mass into the die cavity and built a new filling carriage with a sliding gate, two filling ports, and two mixing devices, which provided high-quality mass averaging during filling and complete filling of the press with powder, first the carriage and then the die cavity. The new filling device combined with a multistep pressing regime eliminated size-separation of the mix and rejection of the green compacts due to cracks and ensured structural uniformity over the entire volume of a part. Control measurements of the apparent density of a green compact at 27 points uniformly distributed over the volume of the part showed an absolute density deviation of 0.02 g/cm^3.

During 2008 specialists at the Borovichi Works will automate the operation of the press using microprocessors and upgrade the hydraulic system of the press, converting the press from water to oil, which will increase the productivity of the press as well as the quality of the compacts by eliminating any influence of the human factor.

Monitoring the technological parameters of the ShSU-33 part production process is organized according to the requirements of the quality management system certified in accordance with GOST R ISO 9001–2001 (ISO 9001:2000) and used in Borovichi Refractory Plant JSC. The established norms must, first of all, satisfy the requirements of the user by warning of any deviations at all stages of the production processes: input monitoring of raw material, monitoring at all stages of production, and acceptance monitoring [5].

As a result of the specific nature of the production, visual monitoring of the green compacts 24 h after pressing for crack presence was additionally introduced for large-block fireclay parts. Careful measurements and checking for deviations from the specifications ensure that the press-tooling assembly is of high-quality. Fired parts are sorted at a separate location with participation of monitoring personnel. Crack parts are discovered primarily during sorting.

Work on the use of instrumentation nondestructive monitoring using an ID2N-PM ultrasonic flaw detector to reveal hidden defects in large parts (interior cracks, separation, voids, and so on) in addition to visual examination is being conducted jointly with "NTTs Ogneupory" Ltd (St. Petersburg). Continuous (100%) nondestructive monitoring will be put into practice in the production of the bottom beam. This will make it possible to guarantee the quality of the parts.

The geometric properties of large-block fireclay parts produced by Borovichi Refractory Plant JSC merit special attention. Refractory parts of two formats are currently being produced serially: No. 1 (1000 × 400 × 300 mm) and No. 2 (1000 × 400 × 200 mm). Parts with all other sizes, including according to GOST 7151–74, are obtained by mechanical working (cutting followed by grinding) of parts with the for-

mats Nos. 1 and 2. Modern glass-making furnaces contain refractory masonry parts with many standard sizes, not only a rectangular but also trapezoidal, triangular, and other shapes, at the bottom. The designers incorporate the following requirements: the refractory parts forming one layer of the furnace bottom must have the same properties, the same linear thermal expansion coefficient, and negligible deviations of the geometric dimensions. To ensure that all these requirements are met, the refractories are cut and ground, and the required openings are made by drilling.

The existing technological equipment makes it possible to meet completely all customer requirements with respect to the geometric parameters of the parts. For example, in January 2008 a batch of No. 1 ShSU-33 refractory parts was produced with geometric dimensional deviations (+ 0, – 1 mm). Two sets of arches, consisting of ribbed wedges (700 × 205 × 134 × 67 and 1000 × 205 × 134 × 67 mm) were fabricated, with cutting and grinding, from No. 1 ShSU-33 refractories for the container furnace at Slavatsteklo JSC. Plates for the top structure of the feeders for glass-forming machines at the Krasnyi Oktyabr' Medical Glass Works (1000 × 400 × 150 and 1000 × 400 × 200 mm) were manufactured in a similar manner.

The texture of a part, observed in section (Fig. 3), is characterized by a fine-grain structure, a uniform distribution of grains of fireclay and binding clay, absence of cracks and separations, chipping of fireclay grains and their detachment from the pointer, and strong binding of the fireclay and binder.

The deviations of unground parts from prescribed dimensions are also small. This is achieved by carefully choosing the technological components of the batch, precisely assembled press tooling, ensuring prescribed fire regimes, and strict monitoring of the technological process. The maximum dimensional deviations and physical – chemical properties of No. 1 ShSU-33 parts (GOST 7151–74), according to the certification results for 36 batches of parts produced by the Borovichi Works from January to October 2007, are presented in Table 1.

In response to queries from glass enterprises, work is being performed on the development of a technology for producing high-alumina (mullite) parts. According to results of a trial production run, the parts meet the requirements for MLS-62 (GOST 24704–94) parts.

Technical Characteristics of Mullite Parts

Indicator	**Actual Values**
Mass fraction, %:	
Al_2O_3	69.1 – 69.6
Fe_2O_3	0.97 – 1.03
Open porosity, %.	18.0 – 19.9
Apparent density, g/cm^3	2.45 – 2.50
Ultimate compression strength, N/mm^2	33.7 – 48.7
Additional linear shrinkage at 1550°C, %	Growth 0.3 – 0.9

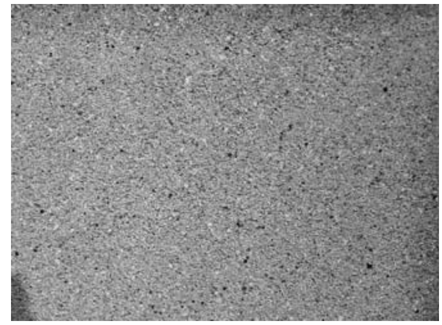

Fig. 3. Texture of a sectioned part.

The data obtained from a statistical analysis of open porosity and ultimate strength under compression, according to the results of certification of the finished product, performed using the BSTAT computer program (the program was developed by St. Petersburg Institute of Refractories JSC), are presented in Fig. 4. Evidently, the open porosity and ultimate compressive strength indicators of the parts substantially exceed the GOST 7154–74 requirements and fall into the following intervals:

open porosity 14.9 ± 1.5%, variation coefficient 10.2%;

ultimate compressive strength 40.3 ± 7.3 N/mm^2, coefficient of variation 18.0%.

In 2007, 890 metric tons of ShSU-33 parts of all formats were produced. The number of parts delivered to users amounted to 294 metric tons. The installed production capacities make it possible to produce up to 4000 metric tons of parts per year. Planned measures to upgrade the press will make it possible to increase this production by at least a factor of 1.5. The ShSU-33 refractory parts produced by Borovichi Refractory Plant JSC have been purchased and used for

TABLE 1.

Indicator	GOST 7151–74 norm	Actual values
Maximum dimensional deviations, mm:		
length	± 6	– 1, + 4/– 1, + 0*
width	± 4	– 1, + 4/– 1, + 0
thickness	± 4	– 0, + 4/– 1, + 0
Mass fraction, %:		
Al_2O_3	≥ 33	39.3 – 40.1
Fe_2O_3	≤ 1.8	1.46 – 1.67
Open porosity, %	≤ 18	13.3 – 16.9
Apparent density, g/cm^3	Not normalized	2.25
Maximum compression strength, N/mm^2	≥ 25	33.2 – 51.8
Additional linear shrinkage at 1400°C, %	≤ 0.4	0.0 – 0.2
Curvature, mm	≤ 2	0.0 – 1.0

* Numerator) unground parts; denominator) ground parts.

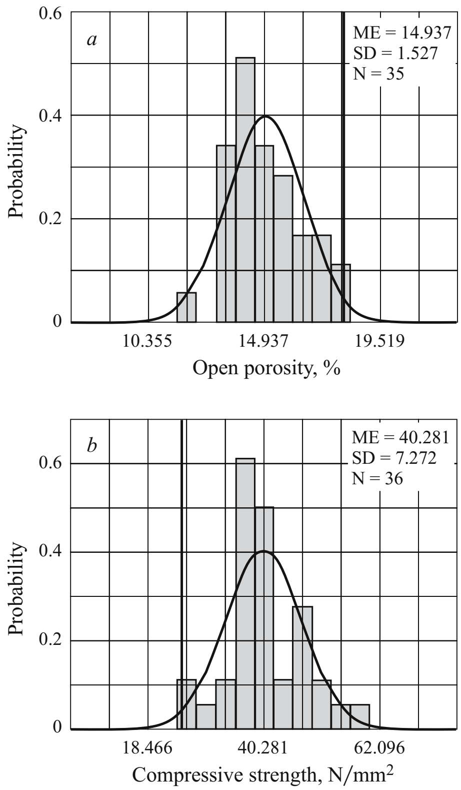

Fig. 4. Statistical analysis of open porosity (*a*) and ultimate compressive strength (*b*) of No. 1 ShSU-33 parts: ME) mathematical expectation; SD) standard deviation; N) number of batches.

the masonry of glass-making furnaces at the following glass enterprises: Volstek JSC (Tver' Oblast), "Peterburgskoe steklo" Ltd (Leningrad Oblast), "Zavod meditsinskogo stekla Krasnyi Oktyabr'" (Vladimir Oblast), "Steklozavod Neman" JSC (Belarus), "Vasil'evskii stekol'nyi zavod" JSC (Tatarstan), Salavatsteklo JSC (Bashkortostan), and "Ufimskii élektrolampovyi zavod Svet" JSC (Bashkortostan).

Positive testimonials concerning the quality of the parts, expressing the fact that the quality of the products is at least as good as that of the products obtained from leading European firms, have been obtained.

In summary, diversifying the production of the aluminosilicate parts, Borovichi Refractory Plant JSC has mastered the production of block parts for glass-making furnaces (bottom beam), manufactured by the method of semi-dry pressing followed by firing in a tunnel furnace, which greatly strengthened its presence on the market for refractories for the glass industry. The production of ground parts with minimum dimensional deviations has now been organized in Russia for the first time.

Organization of production monitoring guarantees that customers will obtain parts with physical and chemical properties, maximum dimensional deviations, and external indicators and internal structure which greatly exceed GOST 7151–74 requirements. Positive testimonials obtained from users confirm that the correct choice has been made for the technical solutions for implementing at the Borovichi Works the production of new products.

In January – February 2008, MLS-62 mullite large-block parts were put into production. A proprietary technology for manufacturing MLSU mullite parts is under development.

REFERENCES

1. L. M. Aksel'rod, G. I. Antonov, E. E. Grinenkov, et al., *Refractory Work: Handbook* [in Russian], Intermet Inzhiniring, Moscow (2002).
2. N. N. Shcherbakov, G. S. Rossikhina, and I. V. Murzin, "Production of large parts from refractory concretes at the Semiluki Refractory Works JSC," *Ogneup. Tekh. Keram.*, No. 12, 39 – 40 (2007).
3. G. S. Rossikhina, N. N. Shcherbakova, M. P. Shchedrin, et al., "Investigation of refractory concrete materials with an aluminosilicate composition by methods of petrography," *Steklo Keram.*, No. 11, 28 – 31 (2007).
4. D. B. Min'kov, V. I. Gromov, and R. Ya. Popil'skii, "Pressing of refractory beams from fine-grain mixes in hydraulic presses," *Ogenupory*, No. 10, 9 – 14 (1968).
5. É. Yu. Panfilova, "Preserving the traditions of quality," *Novye Ogneup.*, No. 6, 33 – 36 (2007).